



# Naval Fuels & Lubricants

## Cross Functional Team

### *Research Report*

## IMPACT ANALYSIS ON THE REMOVAL OF FILTER/MONITORS FROM USN/USMC HELICOPTER IN FLIGHT REFUELING SYSTEMS

NF&LCFT REPORT 441/13-014

26 September 2013

Prepared By:

**JOHN BUFFIN**  
Mechanical Engineer  
AIR-4.4.5.1

**KIM FROWEIN**  
Fuels Systems Team Lead  
AIR-4.4.5.1

NAVAIR Public Release 2013-888  
Distribution Statement A - Approved for public release; distribution is unlimited

*Report prepared and released by:*



**Naval Air Systems Command  
Fuels & Lubricants CFT  
22229 Elmer Road  
Patuxent River MD 20670-1534**

**Reviewed and Approved by:**

<b>Dave Rawlinson AIR-4.4.5.1 Branch Head AIR-4.4.5.1</b>
<b>Richard Kamin Navy Fuels Team Lead AIR-4.4.5</b>

**Released by:**

<b>DOUGLAS F. MEARNS Fuels &amp; Lubricants Systems Engineer AIR-4.4.1</b>

## TABLE OF CONTENTS

Section .....	Page
LIST OF FIGURES .....	iv
EXECUTIVE SUMMARY .....	v
LIST OF ACRONYMS/ABBREVIATIONS.....	vi
1.0 BACKGROUND .....	1
2.0 OBJECTIVE .....	2
3.0 APPROACH.....	2
4.0 DISCUSSION.....	2
4.1 Reasons for Incorporation.....	2
4.2 Utilization of Filter/monitors .....	3
4.3 Filter/monitor Issues .....	3
5.0 RISK IDENTIFICATION AND ANALYSIS.....	3
6.0 RISK MITIGATION MEASURES.....	6
7.0 CONCLUSIONS .....	7
8.0 RECOMMENDATIONS.....	7
9.0 REFERENCES .....	7

**LIST OF FIGURES**

<b>Figure</b>	<b>Title</b>	<b>Page</b>
1	Risk Assessment Probability, Severity, and Color Code Definitions .....	4
2	Filter/monitor Risk Assessment .....	6

## EXECUTIVE SUMMARY

The USAF released a message in July 2005<sup>1</sup> that stated recent single engine flame-out incidents involving three trainer aircraft had occurred, the root cause of the problem had been aircraft filter plugging, and that all water absorbing filters were being removed from service. The investigation by the USAF following the incident indicated that the super absorbent polymer (SAP) used in manufacturing the filter/monitors had migrated downstream and had collected in engine fuel filters and controls, possibly causing the flame-out incidents.

In response to these events, the Navy Fuels Team initiated an investigation into the migration of SAP downstream of filter/monitors, and the resulting risk to aircraft fuel system operation. In June 2007, the Navy Fuels Team released NAVAIRSYSCOM Report 441/07-002<sup>2</sup> that recommended removal of all monitors from land based refueling systems. The report also recommended that a separate risk analysis be performed on the use of filter/monitors containing SAP in helicopter in flight refueling (HIFR) systems. The utilization of monitors in HIFR applications is significantly different than in land-based fueling systems and therefore warrants its own risk assessment. As a result of this risk assessment, the Navy Fuels Team recommends the following:

- The Naval Aviation Enterprise should continue to require the use of fuel quality filter/monitors in HIFR capable aircraft systems.
- The current filter/monitor specification (MIL-PRF-81380E) should be reviewed and updated.
- Filter/monitors should be required to be qualified to the updated specification and the corresponding QPD should be updated.

## LIST OF ACRONYMS/ABBREVIATIONS

DoD.....	Department of Defense
FQM.....	Fuel Quality Monitor
FSII .....	Fuel System Icing Inhibitor
FY .....	Fiscal Year
HIFR .....	Helicopter In Flight Refueling
MARCORSYSCOM.....	Marine Corps Systems Command
NATOPS.....	Naval Air Training and Operations Procedures Standardization
NAVAIR.....	Naval Air Systems Command
ORM .....	Operational Risk Management
QPD.....	Qualified Products Database
QS .....	Quality Surveillance
SAP .....	Super Absorbent Polymer
USAF .....	US Air Force
USMC .....	US Marine Corps
USN.....	US Navy
WOWU .....	Week One Work Ups

# **Impact Analysis on the Removal of Fuel Quality Filter/monitors from USN/USMC Helicopter in Flight Refueling Systems**

## **1.0 BACKGROUND**

For over twenty years the Navy and Marine Corps had been using water absorbent filtration cartridges (filter/monitors, fuel quality monitors (FQMs)) as the final stage of filtration for fixed and mobile aviation fuel delivery systems. Concerns had been growing for many years in regards to performance issues of filter/monitors used in service over an extended period of time. An investigation was conducted by the NAVAIR Fuels Team from 2003 – 2004 to evaluate the service life of the filter/monitors because of the recent decision from the commercial aviation industry to reduce the recommended life of filter/monitors to 12 months. This investigation led to the decision to align the change-out requirement of filter/monitors with standard commercial practice as well as develop a more stringent filter/monitor specification that incorporated the use of fuel with the complete Department of Defense (DoD) additive package.

The US Air Force (USAF) released a message in July 2005<sup>1</sup> that stated recent single engine flame-out incidents involving three trainer aircraft had occurred, the root cause of the problem had been aircraft filter plugging, and that all water absorbing filters were being removed from service. The investigation by the USAF following the incident indicated that the super absorbent polymer (SAP) used in manufacturing the filter/monitors had migrated downstream and had collected in engine fuel filters and controls, possibly causing the flame-out incidents.

In response to these events, the NAVAIR Fuels Team initiated an investigation into the migration of SAP downstream of filter/monitors which revealed that SAP does migrate downstream of filter/monitors, but there is no quantitative test available to measure how much migrates over time. Based on current available materials used for filter/monitor production, manufacturers of the cartridges could not meet a “no detectable amount” specification requirement that a qualitative method would give, so the option to add a limitation to the filter/monitor specification was unavailable.

In June 2007, the NAVAIR Fuels Team released NAVAIRSYSCOM Report 441/07-002<sup>2</sup> that reviewed the requirement to use water absorbent filtration cartridges as the final stage of filtration on USN/USMC fixed and mobile aviation fuel delivery systems. The report, which analyzed the risk of removing the filter/monitors as compared to keeping them in place, recommended that the requirement to use filter/monitors in these aircraft refueling systems be deleted. This decision was based upon the implementation of EI 1581 qualified filter coalescers. EI 1581 filter coalescer performance is superior to earlier styles of DoD filter coalescers. As a result, all filter/monitors were removed from land based service systems and any plans involving the procurement or construction of filter/monitor vessels were cancelled.

The report also recommended that a separate risk analysis be performed on the use of filter/monitors containing SAP in helicopter in flight refueling (HIFR) systems. The utilization of filter/monitors in HIFR applications is significantly different than in land-based fueling systems and therefore warrants its own risk assessment.

## **2.0 OBJECTIVE**

The primary objective of this research effort was to analyze the risk to Navy and Marine Corps HIFR capable aircraft of removing filter/monitors from the HIFR systems and compare that to the risk associated with their continued use.

## **3.0 APPROACH**

The approach used for this analysis was to first determine the reasons why the two inch filter/monitors were originally incorporated into Navy and Marine Corps HIFR capable aircraft HIFR systems. Second, research was conducted to determine how often and for what purpose HIFR-capable aircraft are currently employing their HIFR systems. Third, all known problems associated with filter/monitors used in HIFR capable aircraft were reviewed. Finally, a risk assessment was performed based on all collected data and all known possible risk mitigation measures were reviewed so that the best course of action could be determined.

## **4.0 DISCUSSION**

### **4.1 Reasons for Incorporation**

The decision to use filter/monitors in HIFR systems was made roughly around the same time the decision to use filter/monitors in land based systems was made, somewhere around the late 1960s to early 1970s. In addition to the filter/monitors containing SAP, “go-no go” type filter/monitors were also used. The use of “go-no go” types of filter/monitors was discontinued during the early 1980s when NAVAIR rewrote the filter/monitor specification which only allowed for the use of absorbent polymeric materials.

Filter/monitors were originally incorporated into the fuel filtration process as a final filter for fuel polishing and fail-safe in case of filter coalescer disarming upstream. Their ability to absorb both water and particulate contamination gave the assurance that this last step would ensure delivery of clean, dry fuel. In ship based systems, filter coalescer problems were more prevalent with older DoD style filter coalescer elements and vessels qualified to previous editions of MIL-DTL-15618, but the implementation of filter coalescers that meet the requirements of the most current edition of MIL-PRF-32148 have significantly reduced the water removal and particulate filtration problems experienced with earlier edition elements.

Unlike shore based systems, carriers and large deck air capable ships which utilize deck refueling as the primary method for refueling; the refueling systems on smaller air capable ships provides an alternate method for refueling if deck landing is not possible. The monitor elements



in helicopters refueling systems were incorporated to reduce the probability of water/contamination from being introduced into the airframe fuel system during HIFR from the air capable ships. Although fuel quality assurance requirements apply to all aviation fuel from ships, the fuel quality from an air capable has a higher probability of contamination due to infrequent use and austere conditions in which HIFR is performed.

#### 4.2 Utilization of Filter/Monitors

Filter/monitors in Navy HIFR systems are only being used in the H-60 community. The H-60 HIFR filter/monitors are installed as an emergency fuel filtration device to protect the aircraft if fuel quality is unknown but operational necessity requires refueling. Research indicates that a majority of the squadrons use the HIFR system primarily for training purposes, and in emergency situations to avoid ditching (e.g. a fouled deck, deck unsuitable for landing, aircraft too heavy, etc). At most, training is done once per quarter and during week one work ups (WOWU). These training flights are generally “dry events”, meaning that no fuel is passed through the system.

#### 4.3 Filter/Monitor Issues

As discussed in the background above the SAP can liberate from the monitors and migrate into aircraft systems, the concern is that the amount of SAP in the fuel cannot be measured using available techniques. The recent discovery of this contaminant from the monitor elements means that the consequence associated with this failure mode is not fully understood.

Another issue is that all of filter/monitor elements used on helicopters were qualified to an outdated edition of MIL-PRF-81380 and the commercial specification EI/IP 1583 which does not require use of fuel with FSII. Testing on elements qualified to this specification shows that the filter/monitor’s efficiency to remove free water from the fuel decreases as the amount of FSII in the fuel increases. Fuel system icing inhibitor (FSII) is a mandatory additive in all military aviation fuel specifications.

## **5.0 RISK IDENTIFICATION AND ANALYSIS**

All identified risks associated with the removal of MIL-PRF-81380 fuel quality filter/monitor elements from Naval HIFR systems are from the point of view of the aircraft fuel delivery system. The analysis will determine the risk of removing the fuel quality filter/monitors from the HIFR system on delivering safe-for-flight fuel to the aircraft.

Three risks have been identified: two with the removal of MIL-PRF-81380 fuel quality filter/monitors and one with the continued use fuel quality filter/monitors.

Risk 1: Filter/monitor elements are removed allowing a significant amount of free water to be introduced into the aircraft fuel tanks during refueling due to inadequate system housekeeping (failure to drain filter/separator sumps, failure to strip fuel storage tanks, intrusion of water from outside of fuel piping upstream/downstream of filter/separators).

The consequence is engine flameout caused by a significant amount of water in the fuel.

Risk 2: Filter/monitor elements are removed allowing a significant amount of particulate matter to be introduced into the aircraft fuel tanks during refueling due to inadequate system housekeeping (failure to drain filter/separator sumps, failure to strip fuel storage tanks, intrusion of particulate matter from outside of fuel piping upstream/downstream of filter/separators).

The consequence is engine filter becoming clogged and fuel bypassing the filter, which may lead to engine failure.

Risk 3: Filter/monitors in HIFR systems are retained and SAP is liberated from the elements. Consequence is SAP contaminated fuel may clog the engine fuel filters leading to impending engine failure/flameout. (This is the mode of failure that the USAF indentified for the trainer engine flameouts in July 2005.)

The identified risks were analyzed using the methodology of OPNAVINST 3500.39B<sup>3</sup> and the Hazard Analysis of NAVAIRINST 3960.4B<sup>4</sup>. The probability of the event occurring as well as the severity of damage if the event occurred was considered. The results are displayed within a color coded matrix which graphically shows the level of risk for each event. The probability categories, severity categories, and risk assessment color codes are defined in Figure 1.

Probability Categories	Severity Categories
A – will occur	I – may cause death and/or aircraft loss
B – may occur over time	II – may cause severe injury or major aircraft damage
C – unlikely to occur	III – may cause injury or minor aircraft damage
	IV – will not cause injury or aircraft damage
Risk Assessment Color Codes	
<b>Critical</b> – cannot be mitigated by procedures or new technology	
<b>Moderate</b> – can be mitigated by procedures or new technology	
<b>Negligible</b> – mitigation not necessary	

**Figure 1: Risk Assessment Probability, Severity, and Color Code Definitions**

Risk 1: A significant amount of free water is ingested by the engine as a result of removing filter/monitors from HIFR systems.

Probability of occurrence – B

During HIFR refueling, several failures would need to occur in the shipboard fuel filtration/quality assurance system to allow fuel to be delivered to an aircraft with free water. The probability of this occurrence under normal operations is low; however the operational conditions when the HIFR system is used would typically be emergency and/or non-normal

conditions, increasing the probability of occurrence more likely due to lack of filtration time available and difficulty visually detecting contamination.

Severity if event occurs – I

Since the HIFR system is designed for use while the aircraft is in flight, fuel taken on board will not have enough time to settle in the tanks and any free water that is introduced into the system will remain in suspension. With the filter/monitors removed, there is no protection against water contamination.

Risk 2: A significant amount of particulate matter is ingested by the engine as a result of removing filter/monitors from HIFR systems.

Probability of occurrence – C

During HIFR refueling, several failures would need to occur in the shipboard fuel filtration/quality assurance system to allow fuel to be delivered to an air craft with particulate matter. Large FOD would be captured in HIFR refueling nozzles, and the engine has an engine fuel filter and is tested for particulate contamination to the tables in the engine specification. The probability both the shipboard filtration and quality assurance systems failing and followed by aircraft filters clogging failing both engines is low.

Severity if event occurs – I

Once the engine filter is bypassed contaminated fuel will be delivered to the engine and could severely damage fuel wetted engine components leading to failure.

Risk 3: A significant amounts of SAP material FOD is liberated into the aircraft fuel system from filter/monitors in HIFR systems.

Probability of occurrence – C

SAP migration downstream of the filter/monitor has been verified by military and commercial test cells and laboratories, but the amount cannot be determined quantitatively. Given the previous long term use of these elements at military facilities, with one USAF reported aircraft event, the probability that excessive amounts are liberated is low. The scheduled replacement time for the monitor of one year provides further mitigation.

Severity if event occurs – II

Once the engine fuel filter is bypassed, contaminated fuel will be delivered to the engine and could severely damage fuel wetted engine components leading to failure.

The completed filter/monitor risk assessment matrix is shown in Figure 2.

		SEVERITY			
		I	II	III	IV
PROBABILITY	A				
	B	Risk 1			
	C	Risk 2	Risk 3		

**Figure 2: Filter/Monitor Risk Assessment**

## 6.0 RISK MITIGATION MEASURES

There are two courses of action: (1) continue to use filter/monitors in HIFR systems or (2) delete the requirement and remove the elements from service. Risk mitigation measures are required in either case.

Option 1: Filter/monitors continue to be required in HIFR capable aircraft.

Release naval message stating that all HIFR operational training should be dry run only. No fuel should be flowed through the elements during training exercises. HIFR systems shall be used to meet operational requirements and emergency use only. Address time and change out criteria in naval message.

Option 2: Filter/monitors are removed from the HIFR system and no longer required in HIFR capable aircraft.

Increase aviation fuel QS requirements in NAVAIR 00-80T-109.

Increase preventative maintenance requirements for shipboard fuel delivery systems and equipment.

Develop a fuel monitoring system to replace HIFR filter/monitors that would be capable of filtering particulate, sensing water contamination in real time, and notify the pilot of potential contamination.

## **7.0 CONCLUSIONS**

1. Risk is greater to the HIFR capable aircraft by removing the HIFR filter/monitor elements.
2. Risk and impact of potential free water contamination to the engine is greater than SAP contamination from the filter/monitor.

## **8.0 RECOMMENDATIONS**

1. Maintain the use of filter/monitors in HIFR capable aircraft.
2. Release naval message stating HIFR operational training shall be dry run only. Fuel shall only be flowed through HIFR systems only to meet operational requirements and emergencies. Address time and change out criteria in message.
3. Update pertinent NATOPS and training manuals to reflect the proposed way forward.
4. Review and update MIL-PRF-81380E. Updated specification will tailor testing to simulate HIFR conditions, i.e. water slug testing, SAP migration and 10 ppm maximum effluent free water.
5. Qualify HIFR filter/monitors to the revised MIL-PRF-81380 specification and update corresponding Qualified Products Database (QPD). Qualification program is approximately \$20K and the new monitor elements would be preferred spares.

## **9.0 REFERENCES**

1. USAF Message: AFPET to HQ, Subject: Water Absorbent Filter Elements (Two, Four, and Six Inch Diameter)
2. NAVAIRSYSCOM Report 441/07-002, Impact Analysis on the Removal of Fuel Quality Filter/monitors from USN/USMC Refueling Systems and Equipment, 11 June 2007.
3. Operational Risk Management Guide, Naval Safety Center. OPNAVINST 3500.39B, dated 30 July 2004.
4. NAVAIRINST 3960.3B, Encl (3), App (f), Hazard Analysis

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. <b>PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.</b>				
1. REPORT DATE (DD-MM-YYYY) 09-26-2013		2. REPORT TYPE Technical		3. DATES COVERED (From - To) 09-09-2009-09-25-2013
Impact Analysis on the Removal of Fuel Quality Filter/monitors from USN/USMC Helicopter in Flight Refueling Systems		5a. CONTRACT NUMBER N/A		
		5b. GRANT NUMBER N/A		
		5c. PROGRAM ELEMENT NUMBER N/A		
6. AUTHOR(S) Jack Buffin; Author Kim Frowein; Author Kamin, Richard; Editor Rawlinson, Dave; Editor Mearns, Douglas ; Editor		5d. PROJECT NUMBER N/A		
		5e. TASK NUMBER N/A		
		5f. WORK UNIT NUMBER N/A		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)  Naval Fuels & Lubricants Cross Functional Team 22229 Elmer Road Patuxent River, MD 20670		8. PERFORMING ORGANIZATION REPORT NUMBER NF&LCFT Report 441/13-014		
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Non Program Related Engineering Naval Air Systems Command NPRE Program 22347 Cedar Point Road Patuxent River, MD 20670		10. SPONSOR/MONITOR'S ACRONYM(S) N/A		
		11. SPONSOR/MONITOR'S REPORT NUMBER(S) N/A		
12. DISTRIBUTION / AVAILABILITY STATEMENT A Approved for public release; distribution is unlimited.				
13. SUPPLEMENTARY NOTES N/A				
14. ABSTRACT The USAF released a message in July 2005 that stated recent single engine flame-out incidents involving three trainer aircraft had occurred, the root cause of the problem had been aircraft filter plugging, and that all water absorbing filters were being removed from service. The investigation by the USAF following the incident indicated that the super absorbent polymer (SAP) used in manufacturing the filter/monitors had migrated downstream and had collected in engine fuel filters and controls, possibly causing the flame-out incidents.  In response to these events, the Navy Fuels Team initiated an investigation into the migration of SAP downstream of filter/monitors, and the resulting risk to aircraft fuel system operation. In June 2007, the Navy Fuels Team released NAVAIRSYSCOM Report 441/07-002 that recommended removal of all monitors from land based refueling systems. The report also recommended that a separate risk analysis be performed on the use of filter/monitors containing SAP in helicopter in flight refueling (HIFR) systems. The utilization of monitors in HIFR applications is significantly different than in land-based fueling systems and therefore warrants its own risk assessment. This report identifies the risks and provides recommendations.				
15. SUBJECT TERMS Filter/monitor, risk assessment, HIFR				
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES
a. REPORT UNCLASSIFIED	b. ABSTRACT UNCLASSIFIED	c. THIS PAGE UNCLASSIFIED	Unclassified Unlimited	19a. NAME OF RESPONSIBLE PERSON Douglas F. Mearns
				19b. TELEPHONE NUMBER (include area code) 301-757-3421